The Center for Marine and Coastal Studies — North Carolina State University



# Dune Stabilization with *Panicum amarum* Along the North Carolina Coast



By
E. D. SENECA, W. W. WOODHOUSE, JR.,
and S. W. BROOME

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CENTER FOR MARINE AND COASTAL STUDIES

NORTH CAROLINA STATE UNIVERSITY
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# PREFACE

This report is published to assist coastal engineers in dune stabilization by the establishment and development of vegetation. The work was carried out under the coastal ecology research program of the U.S. Army Coastal Engineering Research Center (CERC).

The report was prepared by E.D. Seneca, Associate Professor of Botany and Soil Science; W.W. Woodhouse, Jr., Professor of Soil Science; and S.W. Broome, Research Associate in Soil Science; North Carolina State University, Raleigh, North Carolina, under CERC Contract No. DACW72-73-C-0025. Support was received from the North Carolina Sea Grant Program, Office of Sea Grant, National Oceanic and Atmospheric Administration, Department of Commerce, Grant No. 2-35178 and 04-3-158-40; the North Carolina Coastal Research Program; and the North Carolina Agricultural Experiment Station.

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Comments on the publication are invited.

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JAMES L. TRAYERS
Colonel, Corps of Engineers
Commander and Director

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# DUNE STABILIZATION WITH *PANICUM AMARUM* ALONG THE THE NORTH CAROLINA COAST

by

*E.D. Seneca, W.W. Woodhouse, Jr.,*
and *S.W. Broome*

## I. INTRODUCTION

The perennial coastal dune grass *Panicum amarum* Ell. (bitter panicum) (Fig. 1) is distributed on foredunes in a discontinuous manner from New England to Florida, and around the gulf to Texas. The taxonomy, distribution, and habitat preferences of bitter panicum have been described in a study by Palmer (1975). She indicated that this grass is a sterile form of *Panicum amarulum* Hitchc. & Chase (shoredune panicum), and is well adapted to the foredune habitat. The shoot and rhizome systems have the potential to produce new shoots and roots at the respective nodes as described by Dahl, et al. (1974). The growing season (aboveground growth) along the North Carolina coast is from May through October, which is about 2 to 3 months less at this latitude than that of *Ammophila breviligulata* Fern. (American beachgrass). However, unlike American beachgrass which is a temporary stabilizer and often loses dominance within 5 to 10 years along the southeastern coasts, bitter panicum forms a part of the permanent cover along with *Uniola paniculata* L. (sea oats).

There is no universal agreement among dune researchers as to the reason for the discontinuous distribution and, until recently, for the relative sparsity of bitter panicum along much of the coast. Some researchers believe that this grass was grazed out by free-roving livestock, while others feel that certain environmental factors are responsible. Dahl, et al. (1974) noted that it is preferred by cattle to several other dune grasses on the Texas coast. Whatever the limiting factors were in the past, within recent years established stands of bitter panicum on the North Carolina coast have spread and new areas are being colonized.

Earlier dune building and stabilization studies along the North Carolina coast have concentrated on American beachgrass (Woodhouse and Hanes, 1967) and sea oats (Woodhouse, Seneca, and Cooper, 1968). Although American beachgrass is a good dune builder at this latitude, it is attacked by a scale insect, *Eriococcus carolinae* Williams (Campbell and Fuzy, 1972), is susceptible to the mushroom-forming fungus, *Marasmius* sp. (Lucas, et al., 1971), and appears less drought tolerant than sea oats. A controlled environment study with seedlings grown from seed collected along the Atlantic and gulf coasts suggested that temperature is a major factor responsible for the observed replacement of American beachgrass by sea oats south of the Virginia-North Carolina line (Seneca, 1972). A recent study on the Texas coast established that bitter panicum and sea oats were the two best adapted plants tested for

Figure 1. *Panicum amarum* (bitter panicum) near Duck, North Carolina.

dune building and sand stabilizing (Dahl, et al., 1974). In that study, American beachgrass was not successfully established, and bitter panicum was more successfully transplanted and easier to procure and handle than sea oats.

This study began in the spring of 1972 to determine the dune building and sand stabilizing potentials of bitter panicum along the North Carolina coast.

## II. METHODS

### 1. Nursery Propagation.

Plants of bitter panicum were collected from Hatteras Island and Ocracoke Island, North Carolina, in March 1972, to establish a nursery at Clayton, North Carolina (Fig. 2). Single culm (stem) plants were spaced 0.6 meters apart in rows 1.1 meters apart. These transplants were cultivated to control weeds, and fertilized in mid and late summer. By fall, there were about 10 culms for every original one (Fig. 3). This number coverts to about 660 culms per are (100 square meters) in the first year. By the end of the second growing season there were about 1,650 culms per are.

Field experiments with these plants began in the spring of 1973, at Duck and Drum Inlet (Fig. 2). About 2 man-hours were required to prepare 1,000 plants for field planting. Processing included digging, breaking apart into usable transplants (Fig. 4), dipping in a clay slurry, and packaging in reinforced paper to prevent desiccation. These plants and two other dune grasses were used to test the dune stabilization effectiveness of mixed species plantings with primary emphasis on bitter panicum.

### 2. Planting at Duck, North Carolina.

The experimental planting at Duck was located about 300 meters inland on a relatively broad, high, unstabilized sandy site (Fig. 5), which is a part of the barrier island site of the Coastal Engineering Research Center (CERC) Field Research Facility. This area was once part of an aerial practice gunnery range and was largely denuded of vegetation. Stabilization at this site became more of a concern than dune building.

The planting was established on 4 and 5 April 1973, using mechanical procedures developed earlier (Woodhouse and Hanes, 1967). Six planting treatments were replicated three times in 14- by 50-meter plots. Each plot consisted of plants in 14 rows running toward the ocean with 0.9 meters between rows and 0.9 meters between plants within rows except for certain rows in which bitter panicum plants were buried.

The six treatments consisted of: (a) nursery transplants of bitter panicum from Hatteras Island stock; (b) nursery transplants of

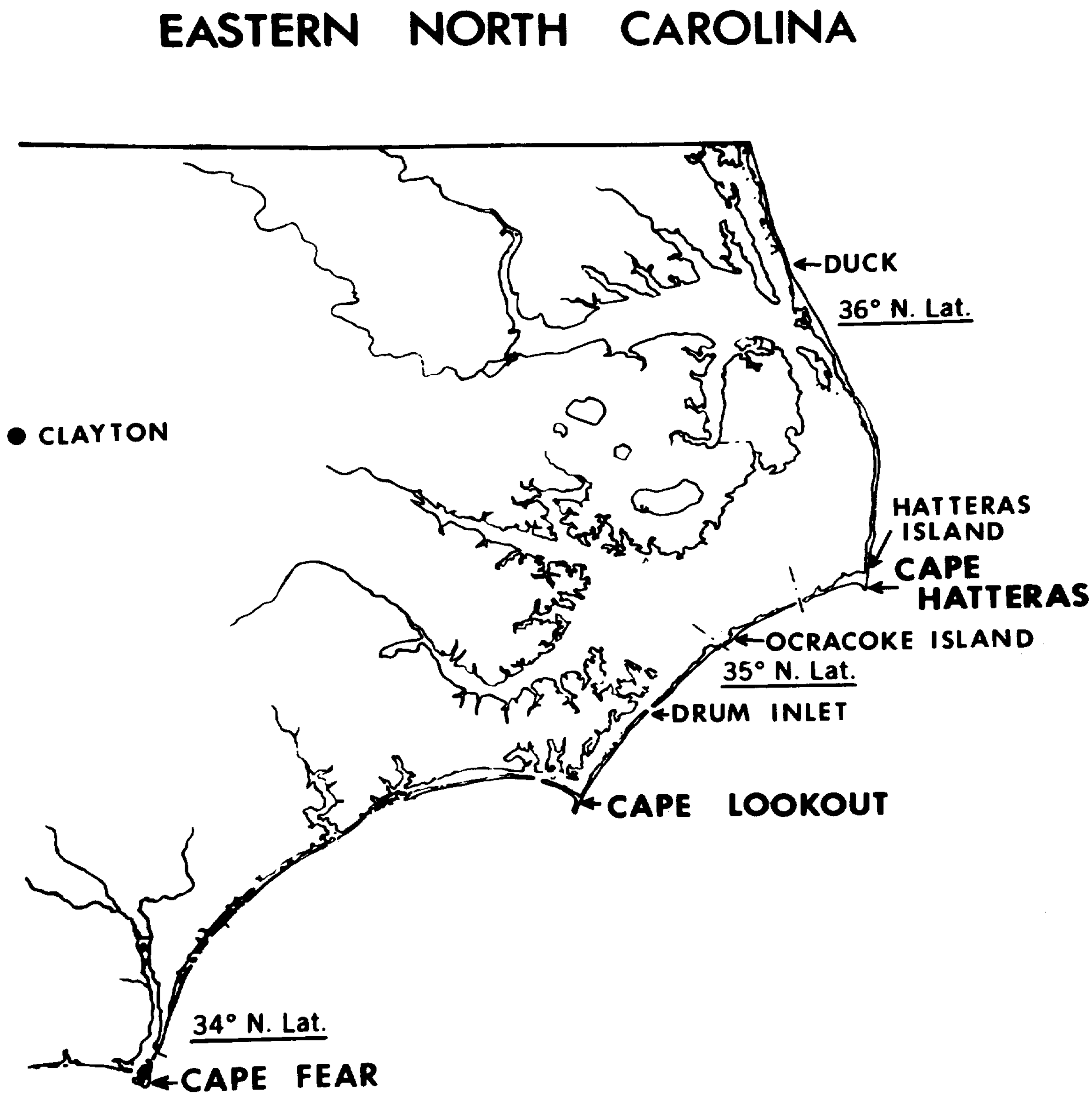


Figure 2. Map of bitter panicum sites of origin (Hatteras and Ocracoke Islands), nursery (Clayton), and experimental planting sites (Duck and Drum Inlet).

Figure 3. Bitter panicum nursery at Clayton, North Carolina, September 1972, 6 months after establishment.

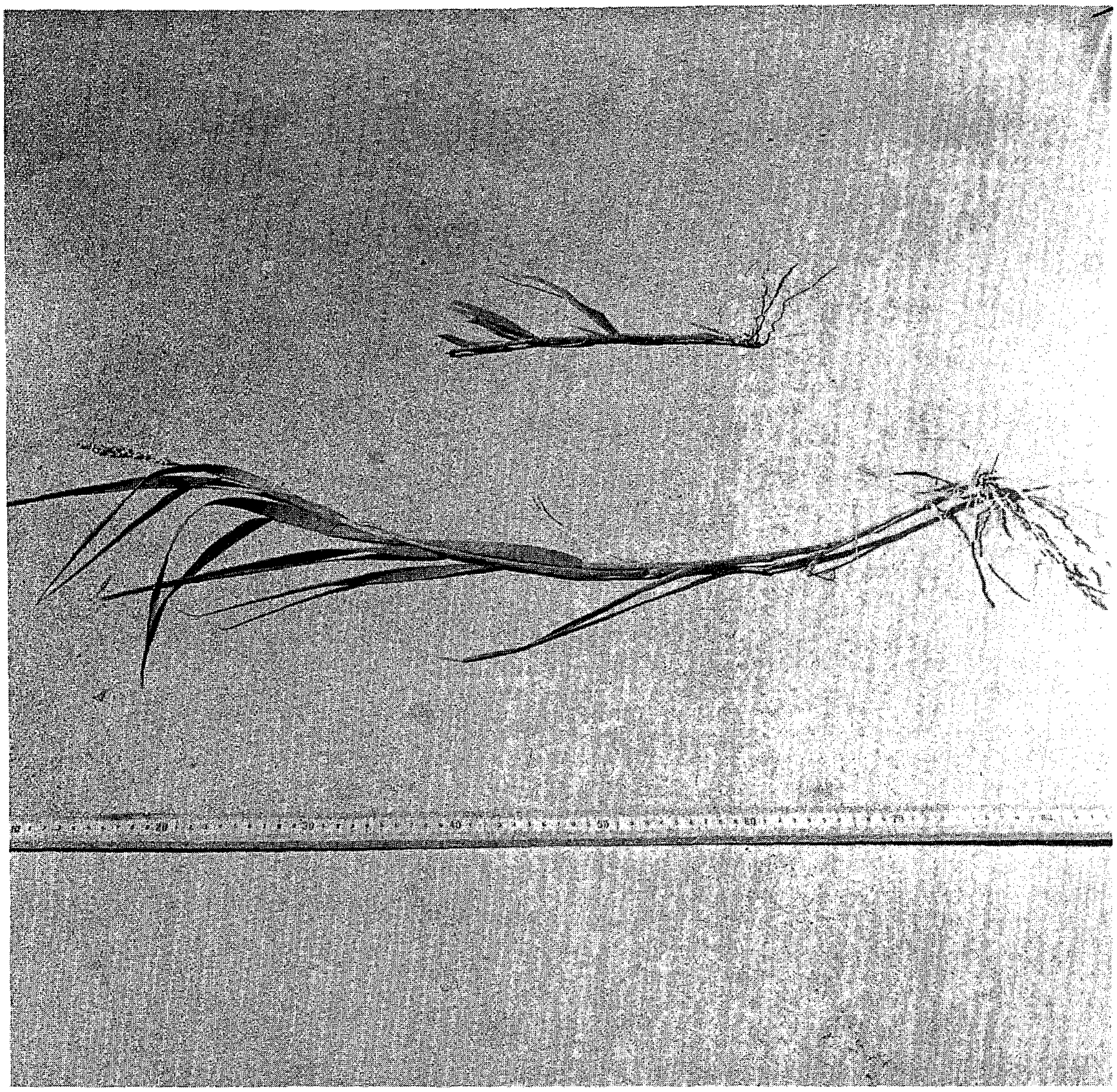

Figure 4. Bitter panicum transplants; top transplant pruned to facilitate machine planting, bottom transplant unpruned.

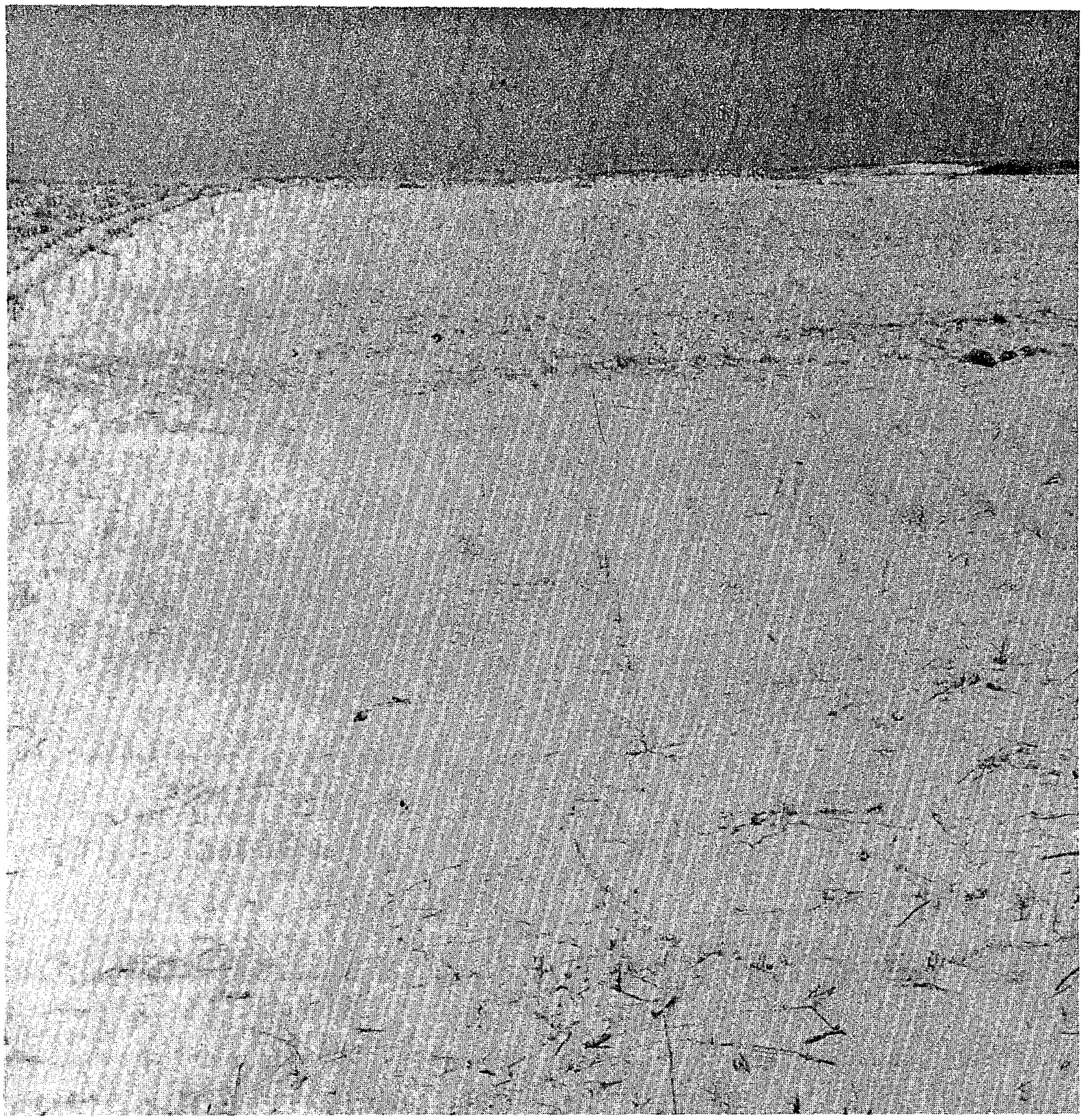

Figure 5. Experimental planting site at Duck, North Carolina, June 1973.

bitter panicum from Ocracoke Island stock; (c) nursery transplants of Hatteras beachgrass, a locally adapted strain of American beachgrass; (d) a combination of transplants used in (a) and sea oats from Duck; (e) a combination of transplants used in (a) and (c); and (f) a combination of transplants used in (a), (c), and (d).

The planting was sampled in October 1973 and 1974. Nine 14-meter transects were sampled in 1973, across the width of each of the 18 experimental plots. A modification of the line intercept technique was used to determine number of leaves, culms (stems), and percentage of the length of the transect actually occupied by shoots (plant cover) for American beachgrass, bitter panicum, and sea oats. A stand count was also conducted on selected plots to compare the number of living bitter panicum plants per row where the entire transplant was buried in a furrow with those established by the conventional upright planting technique.

Five 1-square-meter quadrats (subplots) were sampled in 1974, in each of the 18 plots. The different species present and the estimated combined cover were recorded for each plot. The aboveground vegetation was clipped for selected species for subsequent biomass determinations, and dried at 70° Celsius prior to dry weight determinations for American beachgrass, bitter panicum, shoredune panicum, *Triplasis purpurea* (Walt.) Chapm. (purple sandgrass), and sea oats.

The planting was observed periodically and fertilized at the rate of 56 kilograms of nitrogen per hectare (one time the first growing season and three times the second).

3. Planting at Drum Inlet, North Carolina.

The experimental planting at Drum Inlet was located about 100 meters inland on the level strand 1 or 2 meters above the normal mean high tide level (Fig. 6). There were scattered clumps of native *Spartina patens* (Ait.) Muhl. (saltmeadow cordgrass) and sea oats throughout the planting site. Since the study was concerned with dune building as well as stabilization at this site, a 0.61-meter sand fence (Fig. 6) was constructed in February 1973 to accumulate a ridge of sand before planting.

The planting was established during 13 to 15 March 1973, using mechanical procedures cited earlier. The variably spaced, mixed species planting was designed to determine dune building and dune stabilization response by three species of grass with primary emphasis on bitter panicum. Seven treatments consisted of nursery-grown transplants of: (a) NJ-327 American beachgrass; (b) Cape American beachgrass (Gaffney and Duell, 1974) formerly NJ-390; (c) Hatteras beachgrass, a locally adapted strain of American beachgrass; (d) bitter panicum from Hatteras Island; (e) a combination of (c) and (d); (f) a combination of (d) and sea oats from Drum Inlet; and (g) a combination of (c), (d), and (f). One row of sea oats and two rows of bitter panicum (buried) ran through all plots of all treatments. Saltmeadow cordgrass was not planted. The planting was oriented

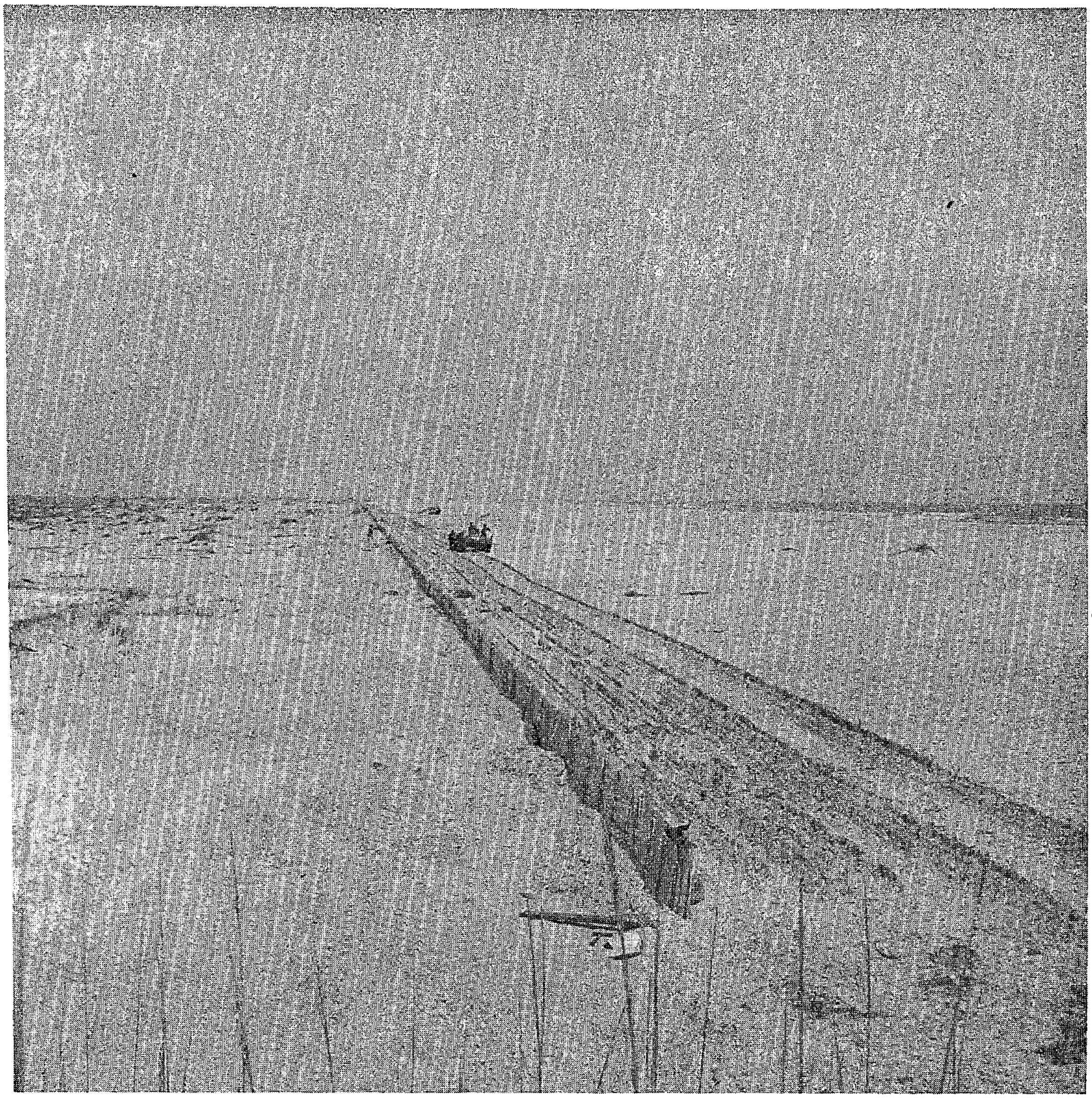

Figure 6. Experimental planting site at Drum Inlet, North Carolina, March 1973.

parallel to the beach with each treatment replicated twice by 14- by 70-meter plots. Within these 16-row plots, the center 4 rows were spaced 0.46 meters apart, the 4 rows on either side of the center 4 rows were spaced 0.76 meters apart, and the outermost 2 rows on either side were spaced 1.1 meters apart. In the spring of 1974, greenhouse-grown seedlings of sea oats were planted 1.5 meters apart on the crest of the dune in barren areas.

The planting was sampled in October 1973 and 1974. The 14 experimental plots were sampled in 1973 in the same manner as those at Duck except that saltmeadow cordgrass was also sampled. Eight 1-square-meter quadrats were sampled in 1974 on the oceanside and 8 on the sound side of the dune in each of the 14 plots. The plant species present and the estimated combined cover were recorded for each quadrat. The aboveground vegetation was clipped by species for subsequent biomass determinations, and dried at 70° Celsius before dry weight determinations for American beachgrass, *Euphorbia polygonifolia* L. (seaside spurge), bitter panicum, saltmeadow cordgrass, and sea oats.

The planting was observed periodically and fertilized twice during the first growing season at the rate of 56 kilograms of nitrogen per hectare. Elevation surveys were conducted in June 1973, 1974, and 1975, by running two cross sections per plot with a level to determine sand accumulation. The experimental area was also repaired in the spring of 1974, by filling gaps with sand and replanting barren areas.

## III. RESULTS AND DISCUSSION

### 1. Duck Planting.

a. 1973. There was little growth in the April transplants by June 1973 (Fig. 5). Although much of the sand was still bare of vegetation in September 1973, surviving transplants of bitter panicum were well established and the area was becoming stabilized (Fig. 7). With the exception of plot 3, which was a mixed species treatment consisting of bitter panicum plus Hatteras beachgrass, the number of leaves, culms, and the cover was greater with bitter panicum than either of the other two dune grasses in all plots of two- and three-species treatments (Table 1). Only bitter panicum yielded cover values of more than 0.50 percent. American beachgrass and sea oats were initially found in scattered clumps throughout the planting site (Table 1).

A count on selected plots indicated the number of living bitter panicum plants was greater in rows where the entire plant had been buried in a furrow than in rows established by the conventional upright planting technique (Table 2). Average percentages of living transplants were 31 for Hatteras beachgrass, 62 for bitter panicum, and 16 for sea oats. Although survival of bitter panicum was good, growth during the first growing season was slow compared to the other experimental

Figure 7. Experimental planting site at Duck, North Carolina, September 1973.

Table 1. Mean number of leaves, mean number of culms, and mean cover per 14-meter transect at Duck, North Carolina, 1973[1].

| Treatment | Plot No. | Mean No. leaves per 14-m transect | | | Mean No. culms per 14-m transect | | | Mean cover per transect (percent) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | A[2] | P[3] | U[4] | A[2] | P[3] | U[4] | A[2] | P[3] | U[4] |
| Bitter panicum (Hatteras) | 1 | 0.78 | 35.33 | 4.22 | 0.44 | 11.00 | 1.33 | 0.02 | 1.35 | 0.11 |
| | 7 | | 30.78 | 7.67 | | 8.22 | 1.33 | | 1.17 | 0.23 |
| | 14 | | 56.78 | | | 14.22 | | | 1.86 | |
| Bitter panicum (Ocracoke) | 5 | | 46.22 | | | 12.78 | | | 1.55 | |
| | 11 | 0.33 | 42.44 | | 0.11 | 12.44 | | <0.01 | 1.40 | |
| | 16 | 1.00 | 21.78 | 17.22 | 0.33 | 8.67 | 4.78 | 0.03 | 0.63 | 0.47 |
| Hatteras beachgrass | 4 | 6.67 | | | 2.00 | | | 0.09 | | |
| | 12 | 5.89 | | 1.11 | 2.33 | | 0.33 | 0.14 | | 0.03 |
| | 13 | 7.22 | | | 2.22 | | | 0.19 | | |
| Bitter panicum (Hatteras) | | | | | | | | | | |
| plus | 2 | 0.56 | 11.33 | 5.11 | 0.22 | 4.00 | 1.11 | 0.02 | 0.39 | 0.11 |
| Sea oats (Duck) | 9 | 0.44 | 9.00 | 2.44 | 0.22 | 5.00 | 0.56 | <0.01 | 0.60 | 0.07 |
| | 17 | | 32.56 | 1.00 | | 10.11 | 0.33 | | 1.12 | 0.02 |
| Bitter panicum (Hatteras) | | | | | | | | | | |
| plus | 3 | 10.89 | 11.22 | 4.56 | 3.22 | 2.67 | 1.33 | 0.15 | 0.30 | 0.09 |
| Hatteras beachgrass | 8 | 3.44 | 28.11 | 0.78 | 1.00 | 7.11 | 0.33 | 0.06 | 0.93 | 0.01 |
| | 15 | 1.89 | 24.56 | | 0.78 | 8.78 | | 0.03 | 0.92 | |
| Bitter panicum (Hatteras) | | | | | | | | | | |
| plus | 6 | 3.56 | 14.44 | | 1.44 | 3.78 | | 0.07 | 0.54 | |
| Sea oats (Duck) plus | 10 | 4.33 | 15.11 | 0.89 | 1.78 | 3.89 | 0.22 | 0.08 | 0.50 | 0.02 |
| Hatteras beachgrass | 18 | 2.44 | 24.89 | 1.00 | 0.89 | 7.22 | 0.22 | 0.05 | 0.79 | 0.02 |

1. Based on nine transects per plot per treatment, n = 162.
2. *Ammophila breviligulata* (American beachgrass).
3. *Panicum amarum* (bitter panicum).
4. *Uniola paniculata* (sea oats).

Table 2. Stand count by treatment for certain plots at Duck, North Carolina, 1973.

| Treatment | Plot No. | Survival[1] (percent) American beachgrass | Bitter panicum buried[2] | Bitter panicum upright[3] | Sea oats |
|---|---|---|---|---|---|
| Bitter panicum (Hatteras) | 1 | | 62 | 56 | |
| | 7 | | | | |
| | 14 | | 73 | 47 | |
| Bitter panicum (Ocracoke) | 5 | | 69 | 50 | |
| | 11 | | | | |
| | 16 | | 59 | 50 | |
| Hatteras beachgrass | 4 | | | | |
| | 12 | 36 | | | |
| | 13 | 29 | | | |
| Bitter panicum (Hatteras) plus Sea oats (Duck) | 2 | | | | 9 |
| | 9 | | | | 13 |
| | 17 | | | | 25 |
| Bitter panicum (Hatteras) plus Hatteras beachgrass | 3 | | | | |
| | 8 | | | | |
| | 15 | | | | |
| Bitter panicum (Hatteras) plus Sea oats (Duck) plus Hatteras beachgrass | 6 | | | | |
| | 10 | | | | |
| | 18 | 27 | 77 | | 16 |

1. Number of living plants divided by the total number of possible transplants per row by standard upright planting technique.

2. Entire transplant buried in a furrow.

3. Transplant planted upright.

planting site at Drum Inlet. There were no noticeable differences in the performance of the selections of bitter panicum from Hatteras and Ocracoke. The low survival of Hatteras beachgrass cannot be explained; it is possible that the transplants were initially of low vigor. The low survival of sea oats is consistent with results from other experiments and those of Dahl, et al. (1975).

b. 1974. Plant cover was estimated to be about 70 percent in June 1974. Of the three dune grasses planted in April 1973, only bitter panicum contributed an appreciable amount of this estimate (Fig. 8). The remainder of the cover was composed of native plants that invaded the planting (Table 3); a few seedlings of American beachgrass and sea oats were observed. *Cenchrus tribuliodes* L. (sand spur), *Diodia teres* Walt. (buttonweed), *Oenothera humifusa* Nutt. (evening primrose), and purple sandgrass were the most widely distributed invading species (Table 4). Only *O. humifusa* is a perennial.

By September 1974, plant cover was estimated to be about 75 percent (Fig. 9). Again, only bitter panicum contributed an appreciable amount of this estimate, with the remainder composed of the invading native plants (Table 3). Purple sandgrass, one of the four abundant invaders, was the most prominent. Although the shoots of bitter panicum were well developed, the rhizomes had not proliferated rapidly over the area. This growth response was possibly due to the lack of sand movement. Bitter panicum is most healthy and vigorous in areas accumulating moderate amounts of sand.

Plant frequency, the percentage of sample plots in which a plant species occurs, is a relative measure of distribution. In the October sampling, values of 60 percent and above were obtained for bitter panicum in all plots of original planting (Table 4). However, for both American beachgrass and sea oats, frequency values were 60 percent or below in the experimental plots; in several plots these species were not recorded in the sample.

Except for plot 18, cover values were 70 percent and above (Table 5). The relatively high cover values were largely due to the invading species, particularly the annual, purple sandgrass.

Bitter panicum contributed about 27 percent of the aboveground dry weight, and averaged about 30 grams per square meter in the plots of original planting, 1, 2, 3, 5, and 6, and where purple sandgrass biomass was also determined (Table 6). Purple sandgrass was sampled for biomass in only six plots, but since it was uniformly distributed it probably contributed at least a minimum biomass of 37 grams per square meter which would be more than that of bitter panicum (Table 6).

2. Drum Inlet Planting.

a. 1973. Survival of transplants in June 1973 was estimated at 75 percent, except for the two rows adjacent to the 0.61-meter sand

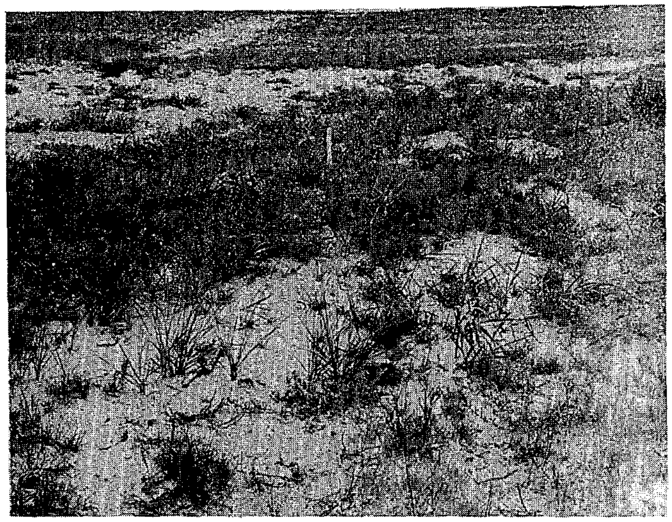

Figure 8. Experimental planting site at Duck, North Carolina, June 1974.

Figure 9. Experimental planting site at Duck, North Carolina, September 1974.

Table 3. Invading flowering plants to the experimental planting at Duck, June and September 1974.

| Name | Growth form | Abundance[1] | Month recorded |
|---|---|---|---|
| *Ambrosia artemisiifolia* L. (ragweed) | herb | infrequent | Sept. |
| *Carex* sp. | sedge | rare | June |
| *Cenchrus tribuloides* L. (sand spur) | grass | abundant | June, Sept. |
| *Chenopodium ambrosioides* L. (Mexican-tea) | herb | rare | Sept. |
| *Cyperus iria* L. (rice flatsedge) | sedge | rare | Sept. |
| *Digitaria filiformis* (L.) Koeler (slender fingergrass) | grass | infrequent | Sept. |
| *Diodia teres* Walt. (buttonweed) | herb | abundant | June, Sept. |
| *Erigeron canadensis* L. (horseweed) | herb | infrequent | June, Sept. |
| *Euphorbia polygonifolia* L. (seaside spurge) | herb | common | Sept. |
| *Ghaphalium obtusifolium* L. (rabbit tobacco) | herb | infrequent | June, Sept. |
| *Myrica pensylvanica* Loisel. (bayberry) | shrub | rare | June, Sept. |
| *Oenothera humifusa* Nutt. (evening primrose) | herb | abundant | June, Sept. |
| *Panicum amarulum* Hitchc. & Chase (shoredune panicum) | grass | common | June, Sept. |
| *Physalis viscosa* ssp. *maritima* (M. A. Curtis) Waterfall (ground cherry) | herb | infrequent | June, Sept. |
| *Spartina patens* (Ait.) Muhl. (saltmeadow cordgrass) | grass | rare | June, Sept. |
| *Triplasis purpurea* (Walt.) Chapm. (purple sandgrass) | grass | abundant | June, Sept. |

1. Scale of abundance from most to least abundant: abundant, common, infrequent, rare.

Table 4. Frequency[1] for 13 plant species at Duck, North Carolina, 1974.

| Treatment | Plot No. | American beachgrass | Sand spur | Slender fingergrass | Buttonweed | Horseweed | Seaside spurge | Evening primrose | Bitter panicum | Shoredune panicum | Ground cherry | Saltmeadow cordgrass | Purple sandgrass | Sea oats |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bitter panicum (Hatteras) | 1 | | 60 | | 60 | 20 | 20 | 100 | 80 | | | | 100 | |
| | 7 | | 40 | | 60 | | | 100 | 60 | | | | 100 | |
| | 14 | | 40 | | 60 | | | 40 | 80 | | | | 100 | |
| Bitter panicum (Ocracoke) | 5 | 20 | 60 | | 20 | | 20 | 20 | 80 | 20 | | | 80 | |
| | 11 | | 60 | | 80 | | | 60 | 100 | | | | 100 | |
| | 16 | | 80 | | 100 | | | 20 | 80 | 20 | | | 100 | |
| Hatteras beachgrass | 4 | 60 | 100 | 20 | 80 | | | 100 | | 40 | | | 100 | |
| | 12 | 40 | 80 | | 80 | | | 80 | | 20 | | | 100 | 20 |
| | 13 | 20 | | 20 | 100 | | | 40 | | 20 | | | 100 | |
| Bitter panicum (Hatteras) plus Sea oats (Duck) | 2 | 40 | 100 | | 80 | 20 | | 40 | 80 | | | | 80 | 20 |
| | 9 | | 40 | | 100 | | | 20 | 100 | | 20 | | 100 | |
| | 17 | | 80 | | 100 | | | 40 | 100 | 60 | | | 100 | |
| Bitter panicum (Hatteras) plus Hatteras beachgrass | 3 | 60 | 100 | | 60 | | 20 | 40 | 80 | | | 20 | 100 | |
| | 8 | 20 | 100 | | 100 | | | 80 | 100 | | | | 100 | |
| | 15 | | 100 | | 100 | | | 40 | 80 | 20 | | | 100 | |
| Bitter panicum (Hatteras) plus Sea oats (Duck) plus Hatteras beachgrass | 6 | | 60 | | 60 | | | 40 | 80 | | 20 | | 100 | |
| | 10 | 40 | 80 | | 80 | | | 80 | 60 | | 20 | | 100 | 20 |
| | 18 | | 60 | | 60 | | | | 60 | | | | 100 | 20 |

1. The percentage of sample plots in which a species occurred, based on five 1-square-meter sample subplots in each replicate (plot) per treatment, n = 90.

Table 5. Mean estimated cover[1] for all plant species at Duck, North Carolina, 1974.

| Treatment | Plot No. | Mean estimated cover (percent) |
|---|---|---|
| Bitter panicum (Hatteras) | 1 | 75 |
| | 7 | 80 |
| | 14 | 80 |
| Bitter panicum (Ocracoke) | 5 | 75 |
| | 11 | 75 |
| | 16 | 75 |
| Hatteras beachgrass | 4 | 80 |
| | 12 | 70 |
| | 13 | 60 |
| Bitter panicum (Hatteras) plus Sea oats (Duck) | 2 | 80 |
| | 9 | 75 |
| | 17 | 75 |
| Bitter panicum (Hatteras) plus Hatteras beachgrass | 3 | 80 |
| | 8 | 80 |
| | 15 | 80 |
| Bitter panicum (Hatteras) plus Sea oats (Duck) plus Hatteras beachgrass | 6 | 75 |
| | 10 | 70 |
| | 18 | 55 |

1. Percentage of ground surface covered by shade as determined by projecting area covered by vegetation groundward, based on five 1-square-meter sample subplots in each replicate (plot) per treatment, n = 90.

Table 6. Mean aboveground biomass[1] for five plant species at Duck, North Carolina, 1974.

| Treatment | Plot No. | Mean aboveground dry wt ($g/m^2$) | | | | |
|---|---|---|---|---|---|---|
| | | A[2] | P[3] | P[4] | T[5] | U[6] |
| Bitter panicum (Hatteras) | 1 | | 67 | | 113 | |
| | 7 | | 17 | | | |
| | 14 | | 46 | | | |
| | $\bar{x}$[7] | | 43 | | | |
| Bitter panicum (Ocracoke) | 5 | 1 | 72 | 2 | 37 | |
| | 11 | | 45 | | | |
| | 16 | | 58 | 6 | | |
| | $\bar{x}$[7] | | 58 | | | |
| Hatteras beachgrass | 4 | 10 | 9 | | 96 | 3 |
| | 12 | 1 | | 5 | | 1 |
| | 13 | 3 | | 3 | | |
| | $\bar{x}$[7] | | 3 | | | |
| Bitter panicum (Hatteras) plus Sea oats (Duck) | 2 | 26 | 6 | | 102 | 25 |
| | 9 | | 85 | | | |
| | 17 | | 91 | 94 | | |
| | $\bar{x}$[7] | | 61 | | | |
| Bitter panicum (Hatteras) plus Hatteras beachgrass | 3 | 15 | 35 | | 149 | |
| | 8 | 5 | 15 | | | |
| | 15 | | 55 | 25 | | |
| | $\bar{x}$[7] | | 35 | | | |
| Bitter panicum (Hatteras) plus Sea oats (Duck) plus Hatteras beachgrass | 6 | | 23 | | 74 | |
| | 10 | 5 | 6 | | | 1 |
| | 18 | | 7 | | | 1 |
| | $\bar{x}$[7] | | 12 | | | |

1. Based on five 1-square-meter sample subplots in each replicate (plot) per treatment, n = 90.

2. *Ammophila breviligulata* (American beachgrass).

3. *Panicum amarum* (bitter panicum).

4. *Panicum amarulum* (shoredune panicum).

5. *Triplasis purpurea* (purple sandgrass); sampled in only one replicate (plots 1 to 6).

6. *Uniola paniculata* (sea oats).

7. Treatment means for bitter panicum only, standard error of the difference among equally replicated treatment means, $s_{\bar{d}} = 21$; $lsd_{0.05} = 47$.

fence where sand accumulation had buried the transplants about 45 centimeters deep (Fig. 10). Dahl, et al. (1975) noted that survival of transplants buried by 15 centimeters or more of sand was less than the upright transplants. Growth and vigor of the surviving plants at Drum Inlet continued to be good through the remainder of the growing season (Fig. 11).

The number of leaves, culms, and the cover in the October sample, was equal to or greater for American beachgrass and sea oats than for bitter panicum in all plots with treatments of two and three species (Tables 7, 8, and 9). All three selections of American beachgrass (NJ-327, Cape, and Hatteras beachgrass) produced greater values for number of leaves, culms, and the cover than the Hatteras selection of bitter panicum in single species treatments. The relatively large values for sea oats were partly due to a row of this species running through all plots. There were also scattered clumps of native saltmeadow cordgrass and sea oats in the experimental area.

b. 1974. Growth of bitter panicum and sea oats was healthier and more vigorous during the 1974 growing season. The increased amount of sand trapped and cover established from 1973 to 1974 was readily apparent (Figs. 12 and 13).

In the October sample, frequency values of 50 percent and above were obtained for the originally planted species (Table 10), except for sea oats in the three-way mixture (Hatteras beachgrass plus bitter panicum plus sea oats) (Fig. 14). Bitter panicum had spread into all six American beachgrass experimental plots, but was more prevalent on the oceanside of the dune. American beachgrass was not found in the bitter panicum experimental plots 4 and 8, and plot 6 of the bitter panicum plus sea oats treatment. Annuals, *Cakile edentula* (Bigelow) Hooker (sea rocket) and seaside spurge, invaded some of the experimental plots (Table 10). Except for plots 10, 12, and 14, cover values were higher on the oceanside than on the sound side of the dune (Table 11). This condition was largely due to burial of first-year transplants on the sound side of the dune sections by about 45 centimeters of sand. In general, cover values were somewhat higher in the plots with bitter panicum than in the three American beachgrass treatments.

Although a few plants invaded the experimental planting, the three originally planted species (American beachgrass, bitter panicum, and sea oats) still constituted 99.5 percent of the aboveground biomass after two growing seasons (Table 12). Bitter panicum provided more cover per unit biomass than American beachgrass. This condition is well illustrated by comparing oceanside of the dune bitter panicum plots 4 and 8 (Fig. 13) with oceanside of the dune American beachgrass plots 3 and 13 (Fig. 15). All of these plots had frequencies of 100 percent, but the bitter panicum plots had higher cover values (Table 11) and the American beachgrass plots had higher biomass values (Table 12).

Figure 10. Sand accumulation on the sound side of 0.61-meter fence at Drum Inlet planting site, May 1973

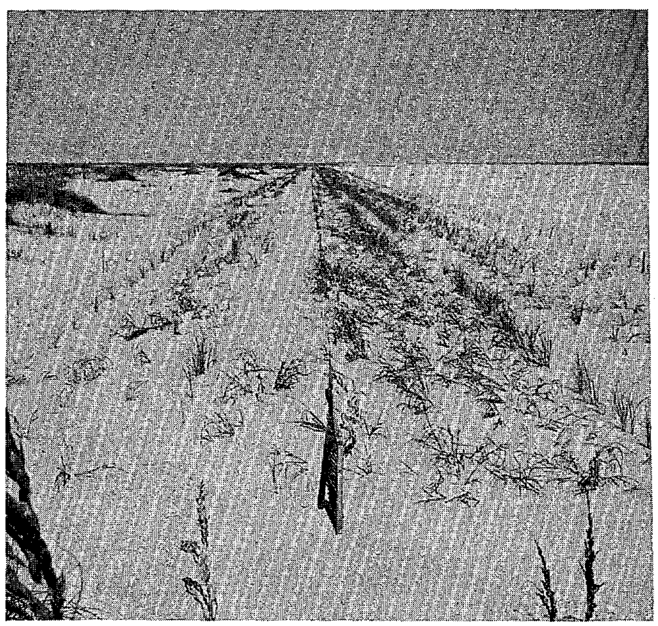

Figure 11. Experimental planting of American beachgrass, bitter panicum, and sea oats at Drum Inlet, September 1973.

Table 7. Mean number of leaves per transect for four dune grasses[1] at Drum Inlet, North Carolina, 1973.

| Treatment | Plot No. | Mean No. leaves per 14-m transect | | | |
|---|---|---|---|---|---|
| | | A[2] | P[3] | S[4] | U[5] |
| NJ-327 American beachgrass | 1 | 104.33 | 0.33 | 2.11 | 4.33 |
| | 12 | 201.67 | 2.78 | 3.78 | 14.33 |
| Cape American beachgrass | 2 | 105.00 | | 4.56 | |
| | 14 | 158.11 | | 5.56 | 3.56 |
| Hatteras beachgrass | 3 | 162.00 | | | 4.67 |
| | 13 | 167.89 | 1.44 | 6.89 | 15.89 |
| Bitter panicum (Hatteras) | 4 | | 69.78 | 0.56 | 4.33 |
| | 8 | | 37.78 | | 15.22 |
| Hatteras beachgrass plus Bitter panicum (Hatteras) | 5 | 78.11 | 17.22 | | 7.89 |
| | 11 | 81.89 | 32.00 | | 59.11 |
| Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 6 | 1.56 | 19.22 | | 66.33 |
| | 10 | 5.33 | 32.44 | 8.44 | 61.33 |
| Hatteras beachgrass plus Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 7 | 29.22 | 9.44 | 3.33 | 19.11 |
| | 9 | 35.78 | 9.89 | | 41.67 |

1. Based on nine transects per plot per treatment, n = 126.

2. *Ammophila breviligulata* (American beachgrass).

3. *Panicum amarum* (bitter panicum).

4. *Spartina patens* (saltmeadow cordgrass).

5. *Uniola paniculata* (sea oats).

Table 8. Mean number of culms per transect for four dune grasses[1] at Drum Inlet, North Carolina, 1973.

| Treatment | Plot No. | Mean No. culms per 14-m transect | | | |
|---|---|---|---|---|---|
| | | A[2] | P[3] | S[4] | U[5] |
| NJ-327 American beachgrass | 1 | 27.56 | 0.22 | 0.09 | 1.33 |
| | 12 | 61.89 | 0.78 | 1.11 | 2.78 |
| Cape American beachgrass | 2 | 31.22 | | 1.67 | |
| | 14 | 42.00 | | 2.67 | 1.33 |
| Hatteras beachgrass | 3 | 37.00 | | | 0.89 |
| | 13 | 36.22 | 0.44 | 2.00 | 3.44 |
| Bitter panicum (Hatteras) | 4 | | 15.89 | 0.22 | 1.11 |
| | 8 | | 11.56 | | 4.89 |
| Hatteras beachgrass plus Bitter panicum (Hatteras) | 5 | 17.78 | 5.00 | | 1.89 |
| | 11 | 23.89 | 8.56 | | 13.67 |
| Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 6 | 0.44 | 4.22 | | 18.44 |
| | 10 | 1.22 | 8.67 | 3.89 | 16.11 |
| Hatteras beachgrass plus Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 7 | 10.22 | 3.00 | 1.67 | 5.78 |
| | 9 | 8.00 | 3.11 | | 9.89 |

1. Based on nine transects per plot per treatment, n = 126.
2. *Ammophila breviligulata* (American beachgrass).
3. *Panicum amarum* (bitter panicum).
4. *Spartina patens* (saltmeadow cordgrass).
5. *Uniola paniculata* (sea oats).

Table 9. Mean cover per transect for four dune grasses[1] at Drum Inlet, North Carolina, 1973.

| Treatment | Plot No. | Mean cover per transect (percent) | | | |
|---|---|---|---|---|---|
| | | A[2] | P[3] | S[4] | U[5] |
| NJ-327 American beachgrass | 1 | 2.18 | 0.02 | 0.03 | 0.05 |
| | 12 | 4.01 | 0.04 | 0.05 | 0.26 |
| Cape American beachgrass | 2 | 2.51 | | 0.03 | |
| | 14 | 3.55 | | 0.06 | 0.10 |
| Hatteras beachgrass | 3 | 2.63 | | | 0.16 |
| | 13 | 2.61 | 0.07 | 0.07 | 0.30 |
| Bitter panicum (Hatteras) | 4 | | 1.74 | <0.01 | 0.02 |
| | 8 | | 1.30 | | 0.37 |
| Hatteras beachgrass plus Bitter panicum (Hatteras) | 5 | 1.39 | 0.60 | | 0.14 |
| | 11 | 1.19 | 1.16 | | 1.17 |
| Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 6 | 0.03 | 0.73 | | 1.40 |
| | 10 | 0.14 | 1.30 | 0.08 | 1.30 |
| Hatteras beachgrass plus Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 7 | 0.76 | 0.32 | 0.04 | 0.48 |
| | 9 | 0.81 | 0.38 | | 0.81 |

1. Based on nine transects per plot per treatment, n = 126.
2. *Ammophila breviligulata* (American beachgrass).
3. *Panicum amarum* (bitter panicum).
4. *Spartina patens* (saltmeadow cordgrass).
5. *Uniola paniculata* (sea oats).

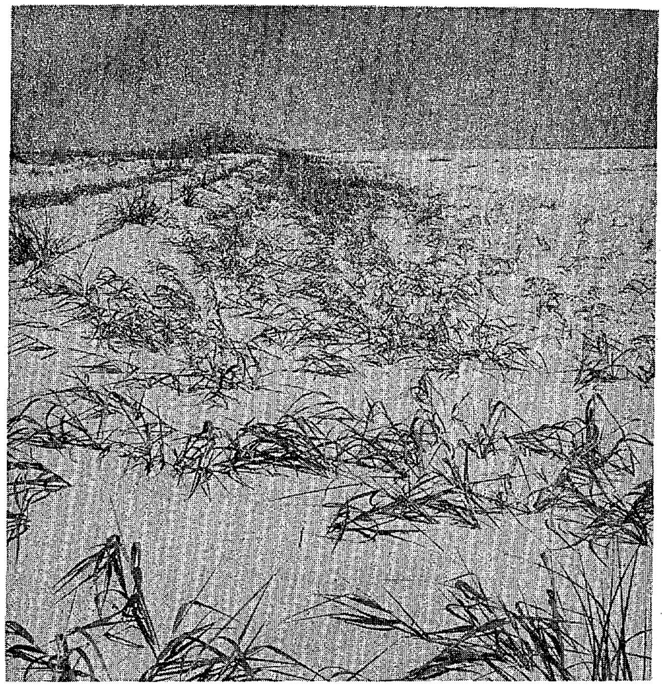

Figure 12. Bitter panicum treatment in experimental planting at Drum Inlet, September 1973.

Figure 13. Bitter panicum treatment in experimental planting at Drum Inlet, October 1974.

Table 10. Frequency[1] for six dune plants at Drum Inlet, North Carolina, 1974.

| Treatment | Plot No. | Oceanside or sound side of dune | Frequency (percent) | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | A[2] | C[3] | E[4] | P[5] | S[6] | U[7] |
| NJ-327 American beachgrass | 1 | ocean | 100 | | | 62 | | |
| | | sound | 100 | | | | | |
| | 12 | ocean | 75 | | | 62 | 12 | 12 |
| | | sound | 88 | | 12 | 25 | | 25 |
| Cape American beachgrass | 2 | ocean | 88 | | 12 | 38 | 12 | |
| | | sound | 100 | | | | | |
| | 14 | ocean | 100 | | 12 | 12 | 12 | |
| | | sound | 100 | 12 | 38 | | 12 | |
| Hatteras beachgrass | 3 | ocean | 100 | | | 50 | | |
| | | sound | 100 | | 25 | | | |
| | 13 | ocean | 100 | | | 62 | | |
| | | sound | 100 | | | 12 | | |
| Bitter panicum (Hatteras) | 4 | ocean | | | | 100 | | |
| | | sound | | | 12 | 50 | | |
| | 8 | ocean | | | 12 | 100 | | 25 |
| | | sound | | | | 88 | | |
| Hatteras beachgrass plus Bitter panicum (Hatteras) | 5 | ocean | 100 | | | 88 | | 12 |
| | | sound | 100 | | 12 | 62 | | |
| | 11 | ocean | 88 | | 12 | 100 | | 25 |
| | | sound | 75 | 12 | 50 | 88 | | 38 |
| Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 6 | ocean | | | 12 | 88 | | 100 |
| | | sound | | | | 50 | | 88 |
| | 10 | ocean | 12 | | | 100 | | 100 |
| | | sound | 25 | 12 | | 100 | | 75 |
| Hatteras beachgrass plus Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 7 | ocean | 50 | | 12 | 75 | | 75 |
| | | sound | 75 | | 12 | 75 | | 75 |
| | 9 | ocean | 50 | | | 88 | 12 | 75 |
| | | sound | 88 | | | 75 | | 12 |

1. The percentage of sample plots in which a species occurred, based on eight 1-square-meter sample subplots on oceanside and eight on sound side of dune per plot per treatment, n = 224.
2. *Ammophila breviligulata* (American beachgrass).
3. *Cakile edentula* (sea rocket).
4. *Euphorbia polygonifolia* (seaside spurge).
5. *Panicum amarum* (bitter panicum).
6. *Spartina patens* (saltmeadow cordgrass).
7. *Uniola paniculata* (sea oats).

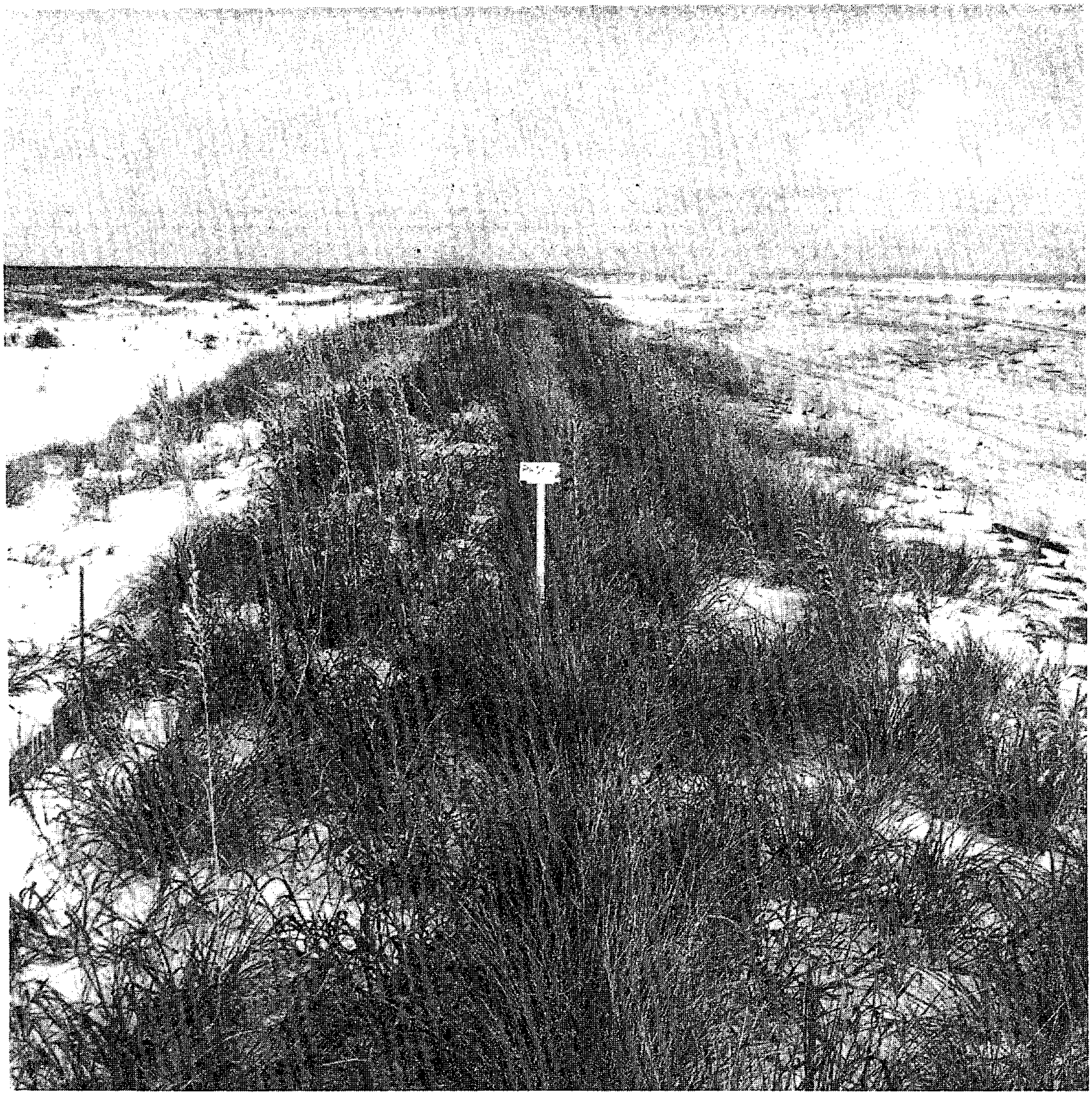

Figure 14. Experimental planting of American beachgrass, bitter panicum, and sea oats at Drum Inlet, North Carolina, October 1974.

Table 11. Mean estimated cover[1] for all plant species at Drum Inlet, North Carolina, 1974.

| Treatment | Plot No. | Oceanside or sound side of dune | Mean estimated cover (percent) |
|---|---|---|---|
| NJ-327 American beachgrass | 1 | ocean | 16 |
| | | sound | 8 |
| | 12 | ocean | 21 |
| | | sound | 22 |
| Cape American beachgrass | 2 | ocean | 16 |
| | | sound | 8 |
| | 14 | ocean | 12 |
| | | sound | 21 |
| Hatteras beachgrass | 3 | ocean | 24 |
| | | sound | 18 |
| | 13 | ocean | 20 |
| | | sound | 14 |
| Bitter panicum (Hatteras) | 4 | ocean | 33 |
| | | sound | 13 |
| | 8 | ocean | 46 |
| | | sound | 16 |
| Hatteras beachgrass plus Bitter panicum (Hatteras) | 5 | ocean | 18 |
| | | sound | 16 |
| | 11 | ocean | 33 |
| | | sound | 29 |
| Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 6 | ocean | 36 |
| | | sound | 33 |
| | 10 | ocean | 26 |
| | | sound | 41 |
| Hatteras beachgrass plus Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 7 | ocean | 17 |
| | | sound | 16 |
| | 9 | ocean | 30 |
| | | sound | 11 |

1. Percentage of ground surface covered by shade as determined by projecting area covered by vegetation groundward, based on eight 1-square-meter sample subplots on oceanside and eight on sound side of dune per plot per treatment, n = 224.

Table 12. Mean aboveground biomass[1] for five dune plants at Drum Inlet, North Carolina, 1974.

| Treatment | Plot No. | Oceanside or sound side of dune | Mean aboveground dry weight ($g/m^2$) | | | | |
|---|---|---|---|---|---|---|---|
| | | | A[2] | E[3] | P[4] | S[5] | U[6] |
| NJ-327 American beachgrass | 1 | ocean | 162 | | 23 | | |
| | | sound | 73 | | | 4 | |
| | 12 | ocean | 120 | | 50 | | 25 |
| | | sound | 223 | 3 | 25 | | 13 |
| Cape American beachgrass | 2 | ocean | 120 | | 43 | | |
| | | sound | 110 | | | | |
| | 14 | ocean | 214 | | 12 | 3 | |
| | | sound | 345 | 1 | 6 | | |
| Hatteras beachgrass | 3 | ocean | 268 | | 6 | | |
| | | sound | 174 | | | | |
| | 13 | ocean | 225 | | 35 | 2 | 1 |
| | | sound | 234 | | | | |
| Bitter panicum (Hatteras) | 4 | ocean | | | 142 | | |
| | | sound | | | 49 | | |
| | 8 | ocean | | | 157 | | 14 |
| | | sound | | | 58 | | |
| Hatteras beachgrass plus Bitter panicum (Hatteras) | 5 | ocean | 142 | | 45 | | 3 |
| | | sound | 100 | | 57 | | |
| | 11 | ocean | 87 | | 117 | | 34 |
| | | sound | 84 | | 58 | | 48 |
| Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 6 | ocean | | | 90 | | 116 |
| | | sound | | | 68 | | 119 |
| | 10 | ocean | | | 86 | | 60 |
| | | sound | 16 | | 200 | | 34 |
| Hatteras beachgrass plus Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 7 | ocean | 99 | 1 | 29 | | 143 |
| | | sound | 24 | | 82 | | 6 |
| | 9 | ocean | 116 | | 82 | 10 | 22 |
| | | sound | 46 | | 33 | | 1 |

1. Based on eight 1-square-meter sample subplots on oceanside and eight on sound side of dune per plot per treatment, n = 224.
2. *Ammophila breviligulata* (American beachgrass).
3. *Euphorbia polygonifolia* (seaside spurge).
4. *Panicum amarum* (bitter panicum).
5. *Spartina patens* (saltmeadow cordgrass).
6. *Uniola paniculata* (sea oats).


Figure 15. Hatteras beachgrass treatment in experimental planting at Drum Inlet, North Carolina, October 1974.

c. Sand Accumulation. Volumes of sand accumulated during the initial 3 months (Table 13) were largely due to sand accumulation by the 0.61-meter fence (Fig. 10), not the planted vegetation. After 3 months, the bitter panicum plots had as much or more sand than the other experimental plots except the American beachgrass plots 1 and 2 (NJ-327 and Cape, respectively). These values had no uniform correlation with the 15- and 27-month values. For example, plots 1, 2, 4, and 6 had higher values after 3 months than the other replicate plots (12, 14, 8, and 10) in the respective treatments, but lower values after 27 months (Table 13). These results indicate that the sand fence did not significantly influence the 15- and 27-month values which were primarily due to the differential sand-trapping potentials of the vegetation.

After 27 months, the three American beachgrass treatments had trapped more sand than all other treatments, and over twice as much as the bitter panicum treatment (Table 13, Fig. 16). The Hatteras beachgrass treatment accumulated slightly more sand over the 24-month period, June 1973 to June 1975, than the other two American beachgrass treatments. Over this same period, the bitter panicum treatment averaged about 1 cubic meter of sand accumulation per linear meter of dune which is about one-fifth as much sand as any other treatment. Even if the best replicate of the bitter panicum treatment is considered, sand accumulation during this period was only 1.9 cubic meters per linear meter or one-third the sand accumulated by other treatments.

All three mixed species treatments accumulated over 5 cubic meters of sand per meter of dune over the 24-month period. Although the bitter panicum plus sea oats treatment accumulated more sand than the other two mixed species treatments, American beachgrass or sea oats planted with bitter panicum accumulated more sand than did bitter panicum alone.

Three treatments (Hatteras beachgrass, bitter panicum plus sea oats, and Hatteras beachgrass plus bitter panicum plus sea oats) trapped over 1 cubic meter of sand per meter of dune more in June 1973 to June 1974, than in June 1974 to June 1975. Only the NJ-327 American beachgrass treatment accumulated more than one-half meter of sand per meter of dune during the second 12-month period. If the supply of moving sand was equal over both years, the vegetation should have caught more sand during the second year since the vegetation was more dense at that time.

Cross-section profiles indicate that the dune crest in all treatments moved seaward about 3 meters from June 1973 to June 1975 (Fig. 16). The dune crest in the Hatteras beachgrass treatment moved the most, about 5 meters. We have observed other experimental American beachgrass dunes move seaward more rapidly than those of sea oats. This movement is due partially to American beachgrass' tremendous vegetative growth (by rhizomes) potential under conditions

Table 13. Cumulative mean volume of sand[1] accumulated over 3-, 15-, and 27-month periods at Drum Inlet, North Carolina.

| Treatment | Plot No. | Volume of sand (cubic meters per meter of dune) by time after planting[2] | | |
|---|---|---|---|---|
| | | 3 months | 15 months | 27 months |
| NJ-327 American beachgrass | 1 | 3.4 | 4.8 | 7.1 |
| | 12 | 2.4 | 7.1 | 10.8 |
| | $\bar{x}$[3] | 2.9 | 6.0 | 9.0 |
| Cape American beachgrass | 2 | 4.0 | 6.7 | 8.8 |
| | 14 | 2.7 | 6.6 | 10.3 |
| | $\bar{x}$[3] | 3.3 | 6.6 | 9.5 |
| Hatteras beachgrass | 3 | 2.7 | 6.9 | 10.7 |
| | 13 | 2.3 | 6.8 | 9.8 |
| | $\bar{x}$[3] | 2.5 | 6.9 | 10.2 |
| Bitter panicum (Hatteras) | 4 | 3.3 | 3.0 | 3.7 |
| | 8 | 3.1 | 4.9 | 5.0 |
| | $\bar{x}$[3] | 3.2 | 4.0 | 4.3 |
| Hatteras beachgrass plus Bitter panicum (Hatteras) | 5 | 2.3 | 4.8 | 7.3 |
| | 11 | 2.6 | 5.4 | 8.4 |
| | $\bar{x}$[3] | 2.4 | 5.1 | 7.9 |
| Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 6 | 3.3 | 5.6 | 7.7 |
| | 10 | 1.7 | 6.7 | 9.7 |
| | $\bar{x}$[3] | 2.5 | 6.2 | 8.7 |
| Hatteras beachgrass plus Bitter panicum (Hatteras) plus Sea oats (Drum Inlet) | 7 | 2.6 | 6.3 | 7.2 |
| | 9 | 2.8 | 6.4 | 9.2 |
| | $\bar{x}$[3] | 2.7 | 6.4 | 8.2 |

1. Based on two elevational cross sections for each of two replicates per treatment.
2. Planting established in March 1973.
3. Treatment mean.

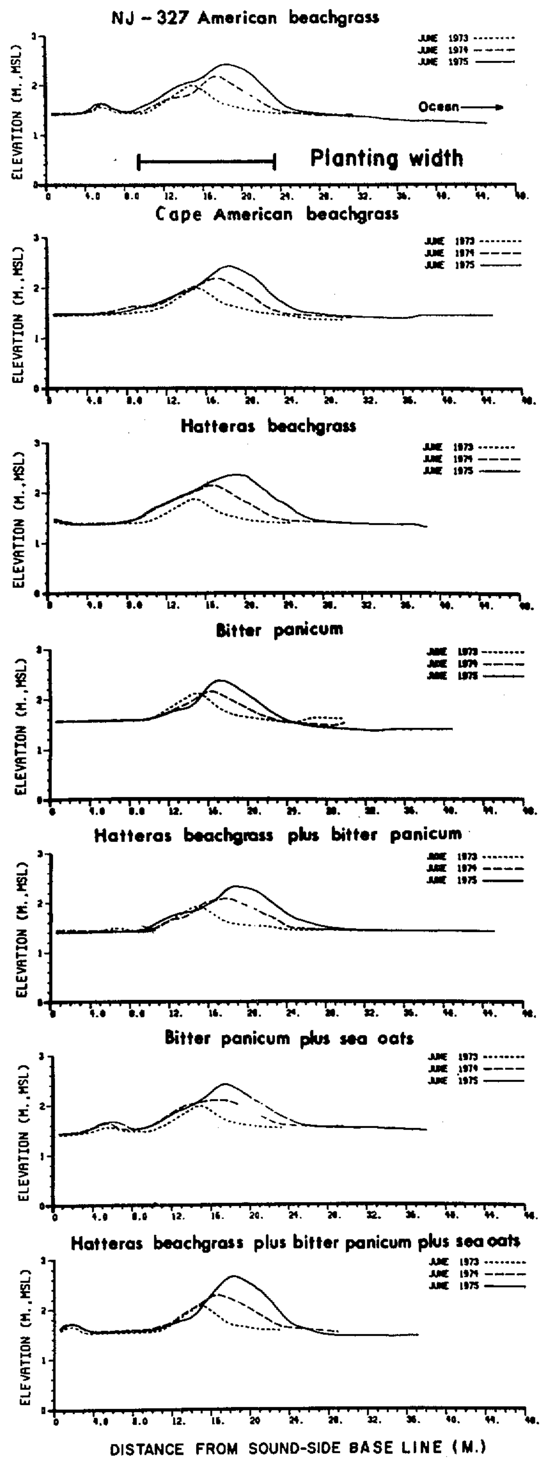


Figure 16. Mean dune cross sections in meters above mean sea level (MSL) for seven treatments at Drum Inlet, 1973 to 1975.

of sand accumulation. Based on the 1975 profiles, oceanside and sound side dune slopes were most gentle in the American beachgrass treatments; the sound side slope was steeper in the other treatments, all of which included bitter panicum. Dune side slopes were steepest in the Hatteras beachgrass plus bitter panicum plus sea oats treatment.

## IV. SUMMARY AND CONCLUSIONS

Single culm transplants of bitter panicum can be planted in an inland nursery, and with routine cultivation and fertilization, can yield a supply of transplants for field planting at the end of the first growing season. A tenfold increase in number of culms was obtained at the end of the first growing season at Clayton, with an additional 2.5-fold increase by the end of the second growing season. The plants should be separated into single culm transplants after digging, dipped in a clay slurry, and packaged in reinforced paper to prevent desiccation. About 2 man-hours are required to dig and process 1,000 transplants for field planting. This is about twice the time required to process an equal amount of American beachgrass transplants.

Bitter panicum has the potential to stabilize foredunes and inland sandy areas. On the high sandy site at Duck, bitter panicum contributed more toward stabilizing the site than American beachgrass or sea oats. However, the American beachgrass planting stock may not have been as vigorous as generally encountered. Although bitter panicum can stabilize an area where relatively little sand is moving, such as the Duck site, the species was more vigorous and spread more at the foredune site at Drum Inlet where moderate amounts of sand were accumulating.

Production of new shoots by bitter panicum plants buried in a 15-centimeter furrow was higher than transplants planted in the conventional upright manner at Duck. However, most of the buried transplants at Drum Inlet were covered by 45 centimeters of sand and unable to grow. Transplants should be planted in the conventional manner in areas accumulating sand, but may be buried in a furrow in nursery plantings and in areas not accumulating much sand. Recent observations suggest that a furrow planting technique which allows the tip end of the transplant to protrude above the sand, may be as good as upright planting, even in areas accumulating sand.

On the foredune planting site at Drum Inlet, each of three selections of American beachgrass accumulated over five times more sand than bitter panicum in a 24-month period. Sand accumulations in mixed species plantings of bitter panicum with American beachgrass and sea oats over this period of time were more comparable with that of American beachgrass alone. Both American beachgrass and sea oats were more efficient sand trappers than bitter panicum.

Cross section profiles indicated that American beachgrass dunes moved seaward more rapidly and had more gentle side slopes than bitter panicum dunes. These findings and other observations suggest that American beachgrass dunes can repair themselves more rapidly following storm attack than dunes with bitter panicum or sea oats.

The length of the growing season, and the width and number of leaves per unit area may be factors related to differential sand accumulation by the three dune grasses tested. The leaves of bitter panicum are wider and generally fewer per unit area than those of either American beachgrass or sea oats. Therefore, bitter panicum may not be as effective at trapping sand. The relatively short (May to October) growing season of bitter panicum compared to the relatively long one (February to November) for American beachgrass at this latitude may be one of the reasons for not accumulating as much sand as American beachgrass. The growing season of sea oats coincides closely with that of bitter panicum; other factors, such as leaf width and density, may be responsible for the differential sand trapping between the two species. Since bitter panicum has a longer growing season at a more southerly latitude, it is probably a better dune builder farther south.

Sand accumulation and dune profile data suggest that bitter panicum should not be used in monospecific plantings to build dunes along the North Carolina coast. The results indicate that the mixed species planting is almost as good at dune building as monospecific stands of American beachgrass. These mixed species plantings are ecologically more desirable because of the insect, disease, and physiological problems associated with American beachgrass at this latitude. In a mixed species planting of American beachgrass, bitter panicum, and sea oats, a dune can be built primarily by the sand trapping potentials of American beachgrass and sea oats; when American beachgrass begins dying out, it can rapidly be replaced by the other two native grasses to stabilize the area. The principal values of bitter panicum are in stabilizing sandy coastal areas and in mixed species plantings to build and stabilize coastal dunes in the southeastern United States.

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